Linear Collider R&D

~~Dave Finley~~ Son getting married

~~Steve Holmes~~ Run II

Bob Kephart New head of Tech Div
= plausible deniability?

HEPAP meeting at Fermilab
April 26, 2002

Outline

- Linear Collider at Fermilab !
- US Linear Collider R&D Program
- LC R&D Activities at Fermilab
  - NLC
  - TESLA/SCRF
- Site Studies
- Personal Perspective
- Summary

Linear Collider at Fermilab !

- FNAL Director,Mike Witherell, stated in his June 12, 2001 presentation to the DOE/NSF HEPAP subpanel:

  "We propose to the U.S. and to the international HEP community that we work together to build a linear collider at or near the Fermilab site."

- FNAL activity in the U.S. LC R&D program is increasing.
- Goals : Develop the technology to support construction of a linear collider.
  - –initial CM energy of 500 GeV
  - –luminosity of at least 10^{34} cm^{-2} sec^{-1}
  - –upgradable to an energy in excess of 1 TeV.

US Linear Collider R&D Program

- The current U.S. LC R&D effort is largely focused on XBand technology for NLC.
  - –SLAC, FNAL, LBNL, LLNL, (and KEK) are participating in this part
- The TESLA collaboration submitted a TDR to the German government in March 2001 for a linear collider based on superconducting RF technology.
  - –TESLA is an international collaboration
  - –US institutions including FNAL contributed to the TESLA TDR
  - –There is an active international program of R&D in support of TESLA
  - –US participation in this program is limited compared to XBand effort
- Both efforts are aiming for technology demonstrations and/or decisions on the timescale of 2003-04.
- Both efforts face many similar challenges for delivering integrated luminosity
  - – e.g. creating very small emittance beams, preserving their quality through the main linacs, and colliding nanometer sized beams.

Linear Collider R&D at Fermilab

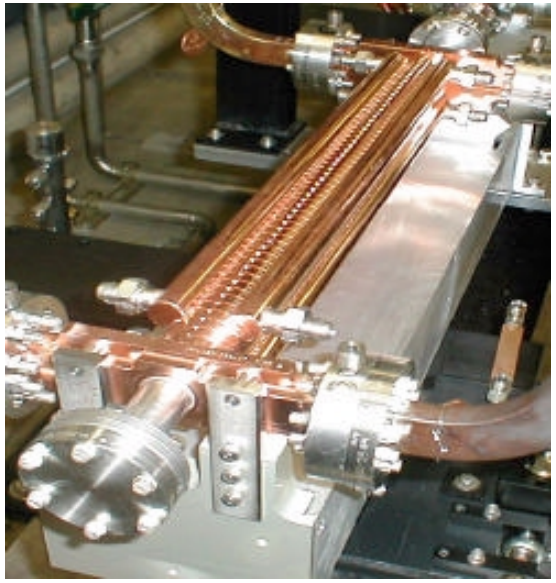
- Fermilab is the only US institution that is both an NLC and TESLA collaborator
- On NLC Fermilab is:
  - –Making RF structures for the 8 pack test at SLAC
  - –Working on industrialization of RF structures
  - –Working on support girder design for the main linac
  - –Investigating adjustable permanent magnet quadrapoles
- On TESLA/SCRF
  - –FNPL (Fermilab NICADD Photo-injector Lab)
  - –EOI for High Brightness Photo-injector (HBPI), with many universities and labs
  - –CKM cavities (SC cavities for separated K beam experiment at FNAL ~TESLA)
  - –Design of 3rd harmonic cavities appropriate for both TTFII and HBPI
  - –Study of the TESLA TDR:Goal = understand costs in US terms and to familiarize FNAL staff with the engineering aspects of the proposal
- For Both : Studies of possible US sites (including FNAL) for a Linear Collider

NLC R&D at Fermilab

- In 1999 Fermilab began working on industrialization of NLC RF structures
- Experience with 1.8 m RDDS structures indicated serious problems with breakdowns ➔Fermilab also joined the effort to understand these problems
- Fermilab is now responsible for the RF structures for the "8 pack test" at SLAC
- Goals of 8 pack test:
  - –Proof of principle demonstration of the NLC RF power generation and distribution system by late 2003
  - –Demonstrate full power, full pulse length, 8 klystron power source with one DLDS arm.
  - –Demonstrate operation of two girders of NLC accelerating structures
    - **10.4 m worth of accelerating structures**
    - **At least one girder made from structures of the "final'' main linac design**
- Industrial production of NLC RF structures is important, since NLC will require ~11,000, 0.9 meter, XBAND accelerating structures to reach 500 GeV in the center-of-mass.

NLC R&D at Fermilab
Structures/Industrialization

- We have set up a structures fabrication facility in Tech Division IB4 with Northern Illinois Center for Accelerator & Detector Development (NICADD) support



53 cm Low Vg RF structure under high gradient testing at SLAC. Achieves gradient of 70 MV/m but still has problem with breakdown @ couplers

FNAL will build similar 60 cm structures for 8 pack test

20 cm test structure recently fabricated at FNAL

"Small" vacuum furnace and the structures fabrication facility at Fermilab. Large furnace for 1.8 m structures is on order

NLC R&D at Fermilab
Structures/Industrialization

- Goals for FY02
  - Complete fabrication facility
  - Fabricate & test three 20 cm structures (LLRF & mechanical tests)
  - Fabricate three 60 cm structures for high power testing at SLAC
  - Achieve production rate of one structure/month (December 2002)
  - Complete structures QC and acceptance criteria
  - Identify vendors and production techniques for main linac structures (include HOM damping & detuning)
  - Reduce costs of production
    - NLC requires 1 MILLION Diamond machined disks
    - Goal = $1000 each → $ 14 each
  - Main Linac design by July 02 to meet 8 pack delivery by Dec 03. (seems unlikely… design will be 6-12 months later than this➔ new schedule at May NLC collaboration meeting ?)

Other NLC R&D at Fermilab

- Permanent magnet R&D (FNAL/LBNL)
  - Close to achieving required 1 μm center stability under adjustment
- XBand Power station at FNAL
  - BD is building the Modulator in FY02
  - 2 klystrons and loads to be provided by SLAC
  - Plan is to use this for high power testing of NLC like XBand structures at FNAL, also a photo-cathode RF gun, studies of tungsten coated iris RF structures (more robust during breakdown?), the test bed for the eventual ETF
- Beam Physics
  - Wakefield analysis code
  - Simulation code for main linac (on hold due to Run II work)

TESLA R&D Program in the US

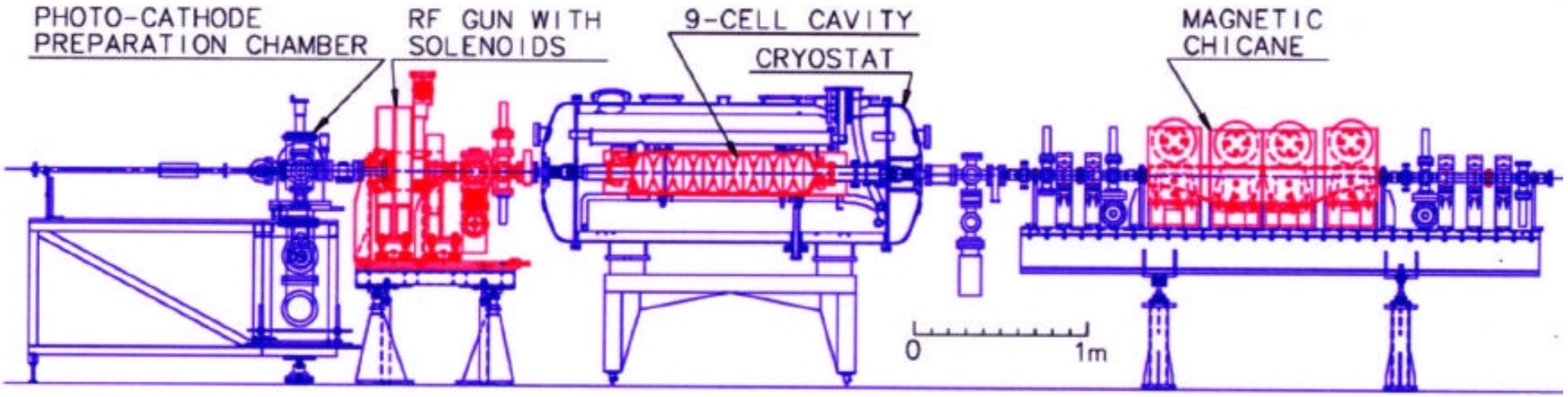
Fermilab is in a key position as a major laboratory in which the technology choice for a linear collider does not appear to be “locked in”.

However the character of the U.S. effort on TESLA is fundamentally different from the NLC program because the TESLA leadership comes from abroad (DESY).

- US members of the TESLA collaboration
  - ANL, Cornell, FNAL, Jefferson Lab, UCLA
- Elements of the U.S. Program
  - SCRF operational experience at Cornell and JLab
  - Collaborated on construction/operation of the TESLA Test Facility (TTF)
  - Injector development (FNPL/TTF and proposal for HBPI)
  - Collaborated on preparation of the TESLA proposal
  - Superconducting materials/processing/fabrication R&D
  - Engineering/cost study of the TESLA proposal

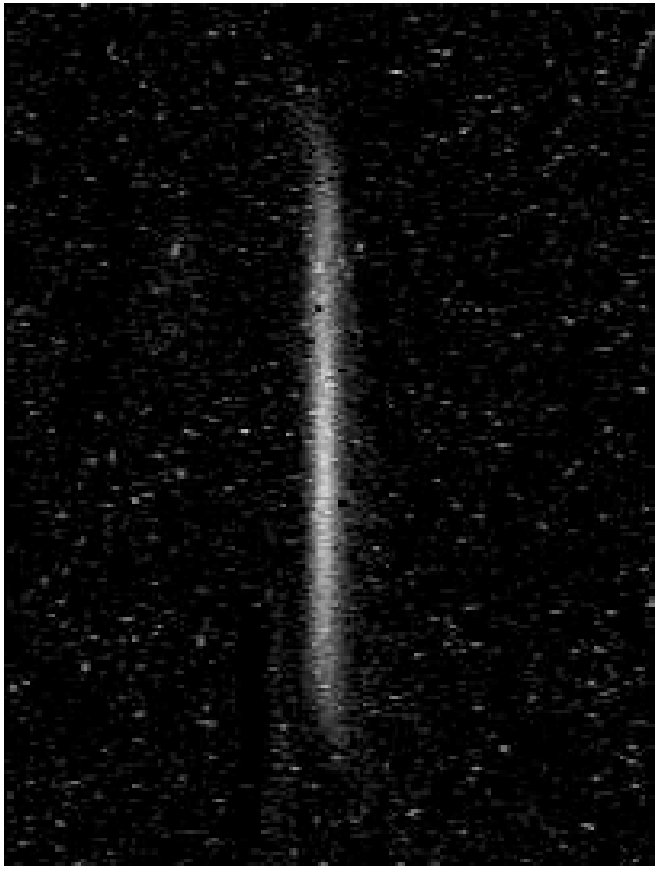
FNPL

- Electron source @ A0
- Jointly operated by Fermilab/NICADD
- Beam Physics
- International Facility (Chicago, Georgia, Michigan, NIU, Rochester, Fermilab, DESY, CERN, LBL)



TESLA/SCRF R&D at Fermilab
Highlights

- Fermilab/NICADD Photoinjector Lab (FNPL)
  - Flat Beam experiments
    - A flat beam injector can simplify damping rings for a LC
    - Goal: Generate a flat beam appropriate for Linear Colliders ($\mathbf{e}_H/e_V \approx 100$)
    - Next step is to increase emittance ratio by decreasing space charge.
  - Other activities:
    - Remote operations demonstration
    - 3.9 GHz (3rd harmonic) cavity to support longer bunches from photo cathode
    - Polarized RF guns?
  - Has produced 5 physics PhD's so far, 3 graduate students on board now.



Typical emittance ratio achieved so far is ~40 @ (17 MeV and 1 nC)

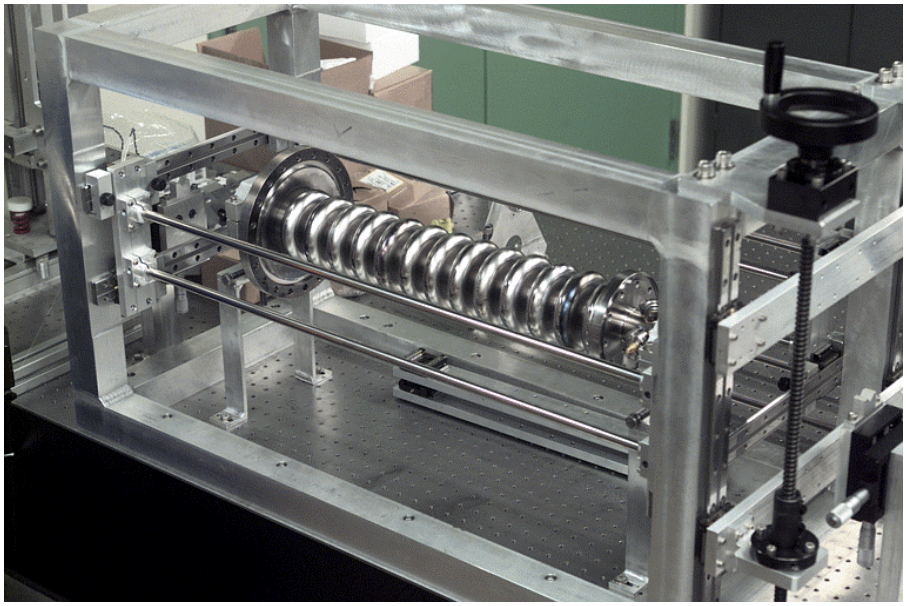
High Brightness Photoinjector at Fermilab

A New high brightness electron source

- Expression of Interest by a lab/university collaboration (Open !)
  - Labs: ANL, DESY, FNAL, LBNL
  - Chicago, Michigan, NIU, Northwestern, Penn, Rochester, UCLA
- Purpose: R&D for linear collider injectors. (Also useful for next generation FELs and synchrotron light sources)
  - A platform to study generation of beams required for LC injectors
  - 1 micron transverse emittances and <270 micron pulse lengths
- Utilizes superconducting RF cavities
  - Will foster Midwest and national development of this technology.
- Fundamental beam and accelerator physics
  - Flat & Polarized Beams, Emittance Reduction
  - Bunch Compression, Wakefield & laser acceleration
- HBPI will contribute to university training of accelerator physicists.

Superconducting RF R&D at Fermilab

- CKM Experiment at Fermilab
  - Measurement of CP violation in $K^+ \rightarrow \pi^+ \upsilon\upsilon$ requires a few 10^{14} K^+
- FNAL will create a seperated K^+ beam with ~ 6 meters of SCRF deflecting cavities operated at 3.9GHz at 5 MeV/m P_{TRANS}
- One and three cell structures have been run up to B_{MAX} of 104 mT on inside Nb surface – compare TESLA (110 mT at 25 MV/m E_{ACC})
- 13 Cell prototype is under construction
- Plan is to build the cavities in U.S. industry
- FNAL will gain valuable expertise relevant to TESLA from building CKM cavities



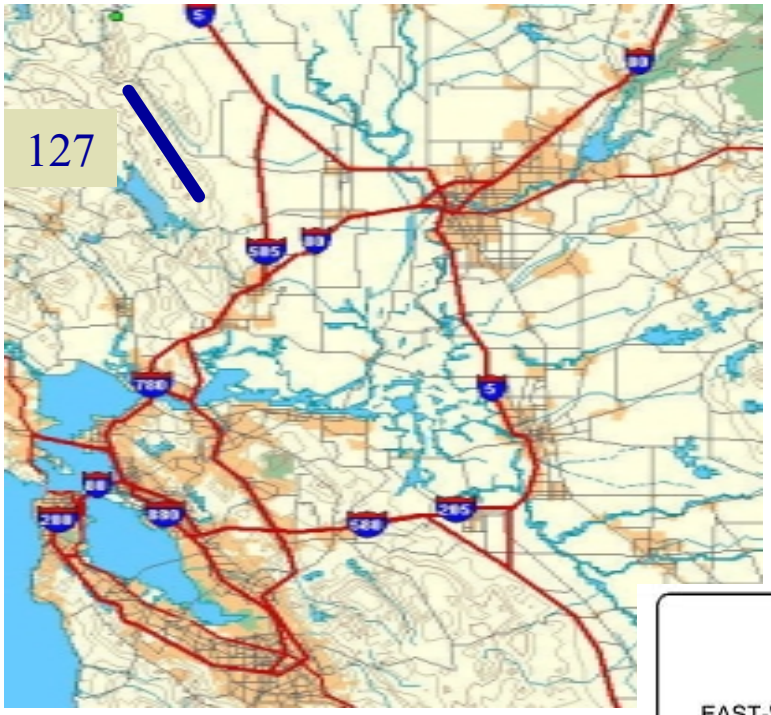
13-cell prototype deflecting cavity

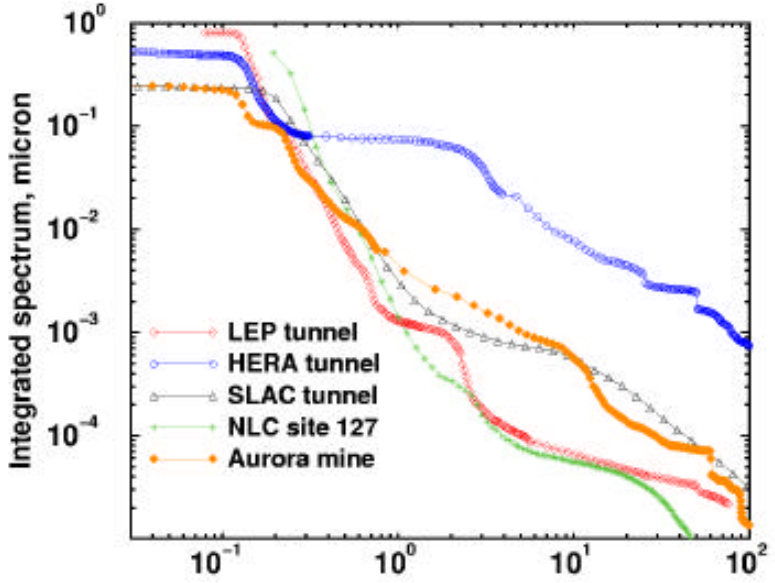
Nb shaped at FNAL, e-beam welded, chemical and heat treatment done at Jefferson Lab.

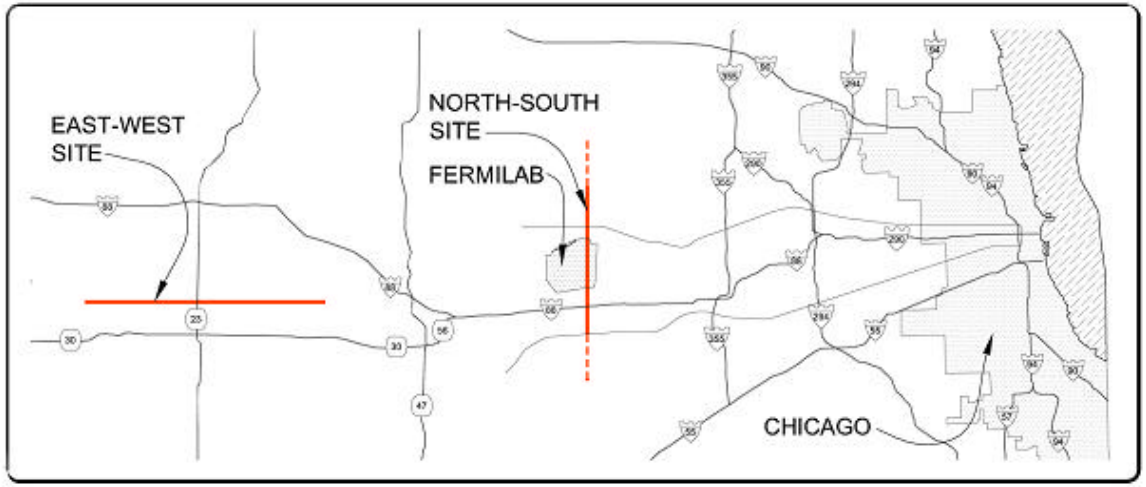
TESLA/SCRF R&D at Fermilab
Highlights

- TESLA Engineering/Cost Study
  - FNAL, SLAC, ANL, Cornell, JLab collaboration
- Goal: To Understand
  - The scope included in the TESLA TDR and cost estimate
  - The supporting studies (industrialization, schedules, etc.)
  - Site specific choices
  - Consequences of implicit (or explicit) implementation choices
  - The methodology (differences between a U.S. and German style estimate)
- Focus = cost drivers
  - main linac (cryo, RF, cavities, etc), civil construction, FEL
- Report should be delivered to lab directors in May.

LC Site Investigations







Personal Perspective
FNAL as Host to the Linear Collider ?

- To serve as a host lab for a US LC FNAL must:
  - Have a command of the basic LC technologies ie warm or cold
  - Host the international collaboration that builds and operates the machine
  - Work with the other labs to optimize the design for the FNAL site
    - TESLA at FNAL need not be limited to 800 GeV
    - NLC at FNAL need not have so many surface buildings
  - Be convinced that the machine is buildable
    - Specifications are reasonable & technology under control
    - The costs are REALLY understood (➔R&D complete)
    - The penalties for being wrong on either will be severe for US HEP!
  - Have the support of the funding agencies and the freedom to make the best technical choices in arriving at the final machine design
  - Have the support of the surrounding community

Personal Perspective
General comments

- To participate in an informed LC technology choice our field as a whole must:
  - Become better informed about the technical issues
  - Participate vigorously in BOTH NLC & TESLA R&D programs
  - Not allow technical choices to be made for political reasons
- Our field needs a forum in which the benefits and problems of these machines can be openly discussed and compared !
- These are activities that ALL of us should and MUST participate in !
  - April 5,2002 “grassroots” meeting on University participation in LC R&D is a good start in this direction!
  - April 19 meeting at Cornell…

Summary

•Linear Collider R&D is being pursued at Fermilab as part of an international program to establishing underlying technologies in 2004 timeframe.

•Fermilab is active in LC R&D effort and the effort is growing
  – Subject to the constraint that Run II must take first priority
•LC R&D needs more resources (people + $) if a LC is to be successful
  – R&D funding for BOTH Xband and SCRF is required if the US is to participate in an informed technology choice
  – Current R&D support levels in the U.S. imperil both our participation in TESLA and in completing NLC R&D on the required timescale
  – The experimental community can help by getting directly involved in the machine R&D and technology discussion.

If we are successful on the R&D (and establishing public support and in forming an international collaboration) then….

our field will construct a Linear Collider over the ~2006-2012 time period and we will begin to do some great physics in 2013!